

A look at human interaction with pervasive computers

by W. S. Ark
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A collection of papers has been gathered in order to explore the pervasive computing trend with a humanistic approach. Is it possible for us to understand what the technological world will be like in the next millennium? These papers will help technologists to share in the successes of others in this field and also to understand problems researchers are having in creating ubiquitous computing environments. Our experiences are conveyed to motivate future work in the area and to help all of us envision and create the future. Because pervasive computing affects many people in any number of disciplines, we took a broad approach when picking topics for this issue. Education, communication, and social implications are among the topics discussed here. Although the means used by the authors to reach for their goals may be different, there are many similarities in their visions of the future.

The purpose of this issue of the *IBM Systems Journal* is to explore the beginning of the pervasive computing revolution. This revolution has begun to affect our everyday lives in ways we do not even notice. Part of the beauty of pervasive computing is that we will not even realize that it is here, once it has become a necessary part of our lives. In the future it will often be invisible, and the user interface will be intuitive. The other important part of the story is that it will all be networked. Data, once entered, will never have to be entered again, but will be readily available whenever and wherever needed. The human-computer interaction (HCI) community has been working toward this type of computing, and now it finally has a name. We discuss pervasive computing from the HCI perspective. (The terms *pervasive*

computing and *ubiquitous computing* are used interchangeably throughout this issue.)

The current phase of pervasive computing, in which computers are already being embedded in many devices, can be thought of in various ways. We see four major aspects of pervasive computing that appeal to the general population:

- Computing is spread throughout the environment
- Users are mobile
- Information appliances are becoming increasingly available
- Communication is made easier—between individuals, between individuals and things, and between things

Today we are facing the end of the dominance of the traditional personal computer. Computing is already embedded in more places than just our desktop computers. Computers make our cars run properly with antilock braking systems and power steering. These examples illustrate what seamless computing should be—it can provide wonderful functionality without requiring that the user understand its inner workings. We already know what it is like to live in a world where the physical is being inhabited by the digital. More and more, the digital

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will permeate the physical space in a seamless manner. We will expect computing to be everywhere.

Computers will not only be increasingly mobile, but information will be accessible from any mobile position. We should not have to carry around devices containing our information. Rather, devices will recognize who we are and obtain information about us, through “remembrance agents” or adaptive user models, Internet information storage, or other means.

Information appliances have human-computer interfaces. An information appliance should be easy for anyone to use and the interaction with the device should be intuitive. Careful design is critical for an intuitive interaction with the device. Although the desktop computer can do many things, this functionality can be separated into more appropriate devices. Some examples of successful popular devices are cellular phones, pagers, televisions, wristwatches, and toasters. Of course, there can be times when these devices become difficult to use, but in their basic form, they meet the criteria for information appliances.

Devices will become more “aware.” A device will be more aware of its user and more aware of its own environment. Devices will not only be able to sense the presence of a user but also be able to sense the user’s needs and goals. Devices will be aware of their position and their surroundings. Biosensing will become prevalent throughout the environment, not only for entertainment and medical reasons, but also to enhance person-to-person communication. When devices become more aware, they can be responsive and seem “smarter.” Computers will have the sensory devices analogous to human senses: sight, sound, speech, touch, and smell. Perhaps the best way for computers to really help humans is for computers to become more a part of the physical, human world. Maybe it is the nature of humans to create things with an image of themselves in mind.

Demonstrations

Over the last few years we have been developing hardware and software support for many scenarios that bring the computer to the person and bring the computer into the environment. At the beginning we called it *in situ* computing; now we are starting to call it context-based computing. In one scenario, for example, if you walk up to an exercise machine and you are wearing some sort of identifier—in our case

a personal area network (PAN)—the exercise machine knows how to train you and to reward you. When a user sits down at an exercise machine, the electronic trainer speaks to him or her. In our case, it starts by recognizing the user and recounting what the user has done before on this machine. It may say, for example, “Hi Wendy, it’s been two days since you worked out. I think you’re ready to raise the weight by ten pounds. What do you say we do ten reps (repetitions) at 100 pounds?” A screen allows the user to interact with the machine and change its program. In any case, as the user works out, the exercise machine encourages the user to pull faster, or longer, or slower to get a better workout. In the example, going through the entire ten repetitions causes the system to say, “You’ve had a great workout. Go over to the vending machine and get yourself a reward.” The exercise machine can then give an appropriate reward by activating the vending machine.

Although not part of the demonstration, a foreseeable future includes biosensing. In this scenario, the exercise machine knows how many muscles are working with respect to the person’s capacity. It knows how much the person is perspiring with respect to a normal workout. An intelligent coach can give feedback on the workout. “If you keep working out like this, you’ll look like this (display of projected image) in one year.” The intelligent coach can display body fat count, weight, or whatever is the best motivator for that person, taking into account the person’s mood and personality.

This kind of information could be obtained using emotion technology.¹ This technology uses biosensors that are nonintrusive and virtually invisible to the user. These sensors collect physiological information about the user so that, over a period of time, we can identify the person’s emotional state. With emotional state information, along with the current task, a model of a person’s personality can be developed over a period of years.

We have been exploring a number of other areas: gaze tracking as another way to unobtrusively gain information about a user; the use of computers with the Global Positioning System (GPS); and natural interactions with computers through multimodal input and output. Our initial efforts toward this last model are described by our BlueEyes project.² In addition, we are exploring ways to incorporate gaze tracking, emotion detection, speech recognition, and gesture recognition in a “smart” computer.

Our group has been continuously working on new ways to use computers. Demonstrations such as the ones described earlier have allowed us to explore the field of contextual or *in situ* computing. As computers become more a part of our lives, we all should have a say in how we interact with these computers. So, as you read through these papers, questions about security of information, trusting, and privacy issues will race through your mind. We should challenge ourselves to understand what we want technology to do for us. This issue is not a review of the pervasive computing field; it is a place to look for provocative possibilities: social, cultural, and physical.

Papers in this issue

We wanted to provide a broad picture of pervasive computing with this issue. It is meant to be a global view of projects “in the works.” In order to understand the full spectrum of work in this field, we used broad categories: products, things, and gadgets, subdivided into the areas of education, communication, and infrastructure; intermediaries; input devices; social implications; future directions; and history.

The field of education is a popular testing ground for many new research vehicles. Two papers represent this area, “Classroom 2000: An Experiment with the Instrumentation of a Living Educational Environment,” by Gregory Abowd, and “Making Sharing Pervasive: Ubiquitous Computing for Shared Note Taking,” by James Landay and Richard Davis. Both papers describe enhanced collaborative learning environments.

What is the context of information? Where, when, and how can information be used? “Contrasting Paradigms for the Development of Wearable Computers,” by Chris Baber, David Haniff, and Sandra Woolley, explores this. The authors also give examples of situations where wearable computers are needed. Other papers in the area of communications relate to these questions. In “Wireless Networked Digital Devices: A New Paradigm for Computing and Communication,” Tom Zimmerman describes a world in which communication will be person-to-person, using a standardized personal area network. Humans communicating with devices are as important as devices talking to other devices. Kevin Eustice and coauthors suggest an easy way for humans to interface with the digital world in “A Universal Information Appliance.”

An infrastructure for information is described by Jim Spohrer in “Information in Places.” In the world described here, devices and individuals can access a truly global database.

Our next broad category is intermediaries, things that sit in the stream of our communications to customize and extend the functions that are natively available in the stream. Certainly these are already part of the way the Web is working with proxy servers. Rob Barrett and Paul Maglio discuss intermediaries in their paper, “Intermediaries: An Approach to Manipulating Information Streams.”

The input device is always a limitation. How will people interact with small, mobile devices? How will people interact with larger stationary devices with embedded capabilities? Certainly sensors will be an important part of the future. However, just as we put in information, we must find our way through it. The use of an input device for more than one thing will be a reality in our lives. Shumin Zhai and Barton Smith discuss input devices in “Multistream Input: An Experimental Study of Document Scrolling Methods.”

Social interactions are the focus of our existence. We are social animals, and for any technology to be useful, it must eventually support socialization; otherwise it will not survive. Chris Dyer, Chris Eisbach, and Wendy Ark discuss this subject in “At What Cost Pervasive? A Social Computing View of Mobile Computing Systems.”

Some of the places where we will find context-based computing will be spaces in which we are having social dialog. Bill Mark, in “Turning Pervasive Computing into Mediated Spaces,” shows us SRI International’s vision of the future and discusses the problems already encountered along the way.

As we think about the future of pervasive computing, we must also remember the past. We are honored to have the history of ubiquitous computing at Xerox PARC (Palo Alto Research Center) as written by Mark Weiser before his death. We are thankful to Rich Gold for making the final revisions on the essay and to John Seely Brown for the short commemorative note.

Acknowledgments

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Cited references

1. W. Ark, D. C. Dryer, and D. J. Lu, "The Emotion Mouse," *Proceedings of the HCI International '99 Conference*, Munich, Germany (August 24–26, 1999).
2. See <http://www.almaden.ibm.com/cs/blueeyes>.

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